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Evaluation of Halftone Images by Modulation Transfer

John Price

Paul Kennedy

EVALUATION OF HALFTONE IMAGES by MODULATION TRANSFER

John D. Price and Paul C. Kennedy

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ABSTRACT

This paper concerns an investigation for determining the feasibility of employing methods, similar to those used in conventional continuous tone photography, for determining the modulation transfer of variable area images on lithographic films. It deals with some of the special problems of separating the signal (the image) from the noise (the pattern of the screen), and describes the instruments and approaches to data read-out.

INTRODUCTION

The printing industry has traditionally depended on the eye as the primary instrument for the measurement of image quality. With increasing demand for better reproductions, it has become necessary to look for more objective and sophisticated methods. Some steps have been made in this direction, but generally progress has been slow.

Since photomechanical reproduction has evolved as a craft rather than a technology, little systematic effort has been made to understand image quality. Such efforts would involve the identification and measurement of physical attributes of the image which would correlate with image quality as seen by an observer.

The Lithographic Technical Foundation has applied techniques borrowed from the photographic industry to demonstrate the correlation between an observer's subjective impression of an image and the density gradient across half-tone dot boundaries.[1] Japanese researchers have used a microdensitometer to investigate the structure of the half-tone dot; they have correlated the results with those obtained by measurements of an exposed plate and with a microsope using dark-field illumination.[2]

In continuous tone photography, Modulation Transfer[3] has gained widespread acceptance as a method for appraising films and describing their image-forming capabilities. To determine a film's Modulation Transfer Function, the film is exposed to a sine target of a given modulation and of varying spatial frequency. The response of the film is measured with a microdensitometer, and a comparison is made of its modulation to that of the target at each spatial frequency. A decrease in modulation of the image from that of the target is a measure of degradation or loss of quality. It is the authors' belief that this approach can also be used to investigate the quality of half-tone images.

OBJECTIVES

The purpose of this research was to test the feasibility of applying Modulation Transfer methods to variable area imaging systems and to develop techniques required to obtain modulation transfer information from half-tone negatives.

A major problem was that of devising a way for removal of the noise or unwanted signal introduced by the periodicity of the cross line screen. It was for this reason that a line tint screen was selected for the investigation. The line tint screen has parallel lines in one direction and allows the image to be modulated sinusoidally in the same direction and thus eliminates the influence of the cross line screen.

The microscope, microdensitometer, and optical comparator were tested for their usefulness as read-out devices. The problems and advantages associated with each will be discussed later.

EXPERIMENTAL PROCEDURE

Kodalith Ortho Type 3 film was chosen for this research because of its wide-spread use in industry. Super Kodalith Developer was selected because of its good keeping properties and its compatability with Kodalith film. A 150 lines/inch line tint screen was used because this ruling is common to practice, in addition to the reasons previously mentioned. The 31 step tablet was used because of its density range and small .04 density increments.

Preliminary tests indicated that one of the greatest sources of variability was due to poor or erratic contact between film and screen during exposure. This problem was corrected by the use of a properly designed vacuum register board, allowing sufficient draw-down time and strict adherence to procedures of cleanliness.

The film, line screen, and target (or step tablet) were arranged as shown (fig. A). During exposure each was held in intimate contact by the vacuum register easel. The exposures were made with a voltage regulated point light source which was controlled by a digital timer.

Preliminary exposure tests were made by trial. The optimum exposure level selected was such that the line width of the lowest spatial frequency of the sine target reached a minimum of no less than 15% of the total line width. (fig. B)

Processing was done at 68^{o} F with ASA agitation. A modified Super Kodalith Developer formula was used which contained 16cc of glacial acetic acid per liter of solution A. This modification was made to minimize errors in processing time and agitation.

The next phase of the research was that of determining the variability of the process. Nine step tablet images and three sine target images were exposed and processed in three separate runs. The image which resulted from an exposure to the step tablet was one which contained steps of varying % line widths. For purposes of calibration, the widths of the lines in each of the nine step tablet images were measured with a microscope having a reticle eyepiece. A computer program was then written which calculated the mean and the 95% confidence interval for the % line width of each step. The output of this program is shown in the Appendix and was used to draw the curves shown in figure D. This curve is analogous to the density versus log exposure curve used in conventional photography, and can be used to determine the exposure which a line receives to produce a given width.

The image which results from the sine target test arrangement is formed by the fluctuating density distributions of the screen and the target. This is shown schematically (fig. B) and pictorially (fig. C). To determine the modulation of the image, a measure of the maximum and minimum line widths at the various spatial frequencies was needed.

The first method tested was the use of a microdensitometer. The image was scanned along the length of the lines with a narrow slit aperture whose length was a multiple of the screen ruling. It was hoped that this method of read-out would prove to be satisfactory because of its simplicity. It was found, however, that this approach would not give satisfactory data for three reasons: First, the best aspect ratio for a scanning aperture would integrate only three lines; second, the output of the densitometer was linear with density, and conversion to % transmission gave too few significant figures; third, the non-image density between the lines produced gross errors in the low % line width measurements. This problem also was encountered with the use of the % dot area meter and will be discussed in more detail.

The second approach to the measurement of modulation was the use of an optical comparator. This method proved too tedious; it was difficult to get satisfactory results because of a 200 x limit on magnification and because of the difficulty of seeing the image on the ground glass.

The third method tested for data read-out was the use of a microscope with a reticle eyepiece. This approach provided the quickest and most accurate data. Five readings were taken of each spatial frequency, and the average value was used for the purpose of computing the % line width. The fringes which are found at the edge of the lines were found to be very small and caused no significant problem in the measurement of the image.

The Densichron % dot area meter was tested for the purpose of gathering calibration curve data. It was found that the results correlated poorly with those obtained from the microscope (fig. E). The reason for this failure can be seen in the microdensitometer traces of the density profile of two % line widths(fig. F). Areas between the lines instead of being clear had some density. The integration of this density with the line density resulted in an inflated estimate of the line width, particularly in the low percent line widths.

Once the maximum and minimum line widths for a modulated image have been measured, the log E values which produced them can be found by use of the calibration curve (fig. D). These values were then converted to exposure, and the modulation of the image M_i was then computed by the formula:

$$M_i = \frac{E_{max} - E_{min}}{E_{max} + E_{min}}$$

When this value is divided by the modulation of the target M_t, the modulation transfer factor for a given step is obtained.

$$MTF = \frac{M_i}{M_t}$$

The Modulation Transfer Function describes the modulation factors at all spatial frequencies under consideration (fig. G)

DISCUSSION

This work has demonstrated the feasibility of applying modulation transfer techniques to the evaluation of half-tone images, and has shown the results obtained from a particular set of materials and techniques.

Through application of outlined method, one could systematically investigate the effect of various parameters of a process and determine their effect. Agitation, developers, quality of illumination, and the ruling of the screen are but a few of the possibilities for investigation.

One important extension of this work would be that of investigating the correlation between MTF and conventional subjective descriptors. Once these relationships are understood, MTF data could be used to infer the visual appearance.

It was learned that the system under investigation is capable of resolving information ~~if~~ in excess of that which could be observed with the unaided eye. An important consideration to be investigated is the effect of the micro image on the macro appearance.

By designing special area modulated sine targets is should be possible to extend this technique to other parts of the photomechanical system where the problems of modulation transfer are apparently more acute.

FOOTNOTES

1
Jorgensen, G. W., "Sharpness of Half-tone Images on Paper," Lithographic Technical Foundation Research Progress, # 47, July, 1960.

2
Tajima, M., Komatsu, Y., and Miyauchi, T., "Techniques for Evaluating Dot Quality in Halftone Processes," Photographic Science and Engineering, V. 8, # 4, July-Aug., 1964, p. 216.

3
Mees, C. E. Kenneth, The Theory of The Photographic Process, Macmillan Co., N. Y., 1966, p. 512-14.

ACKNOWLEDGEMENTS

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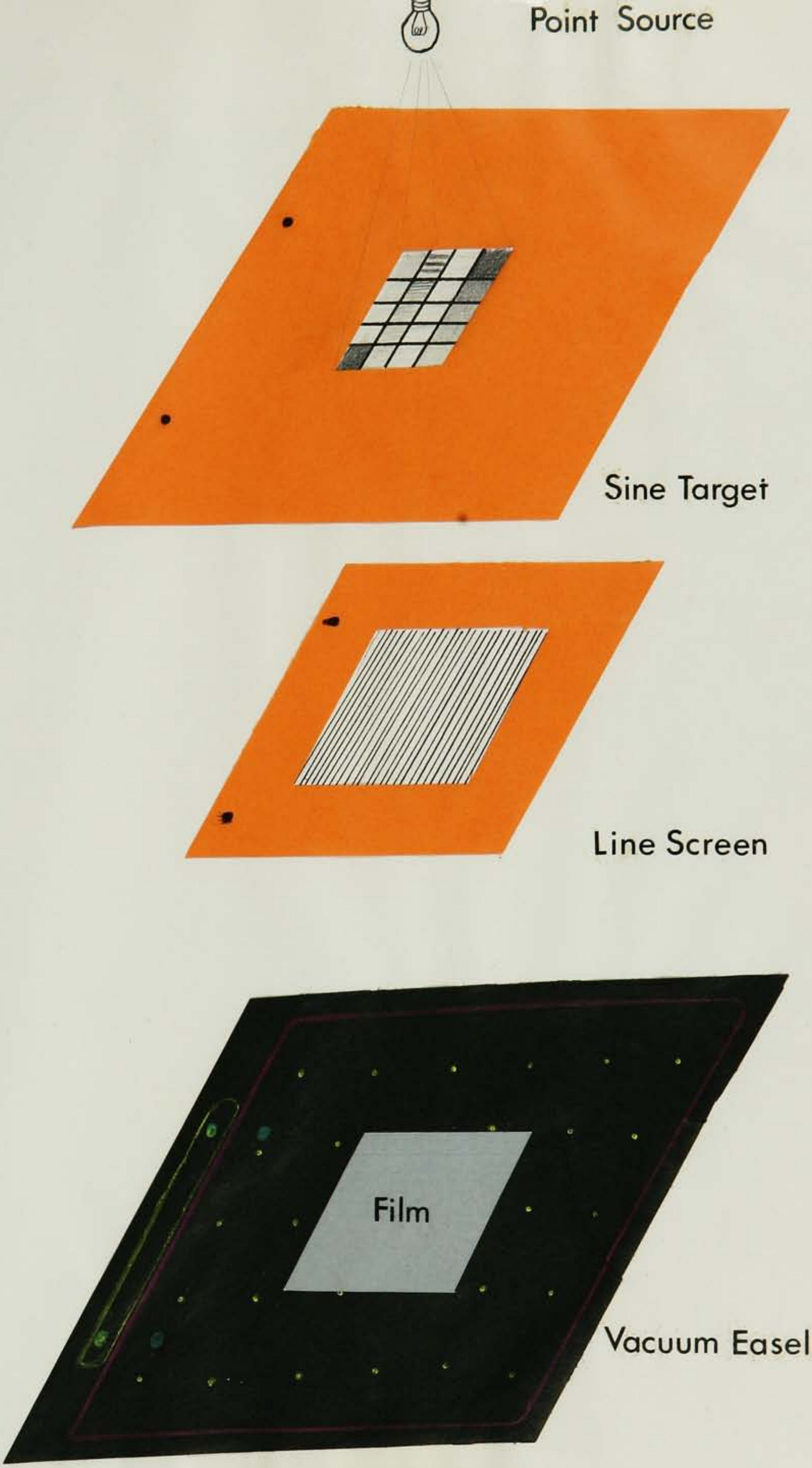
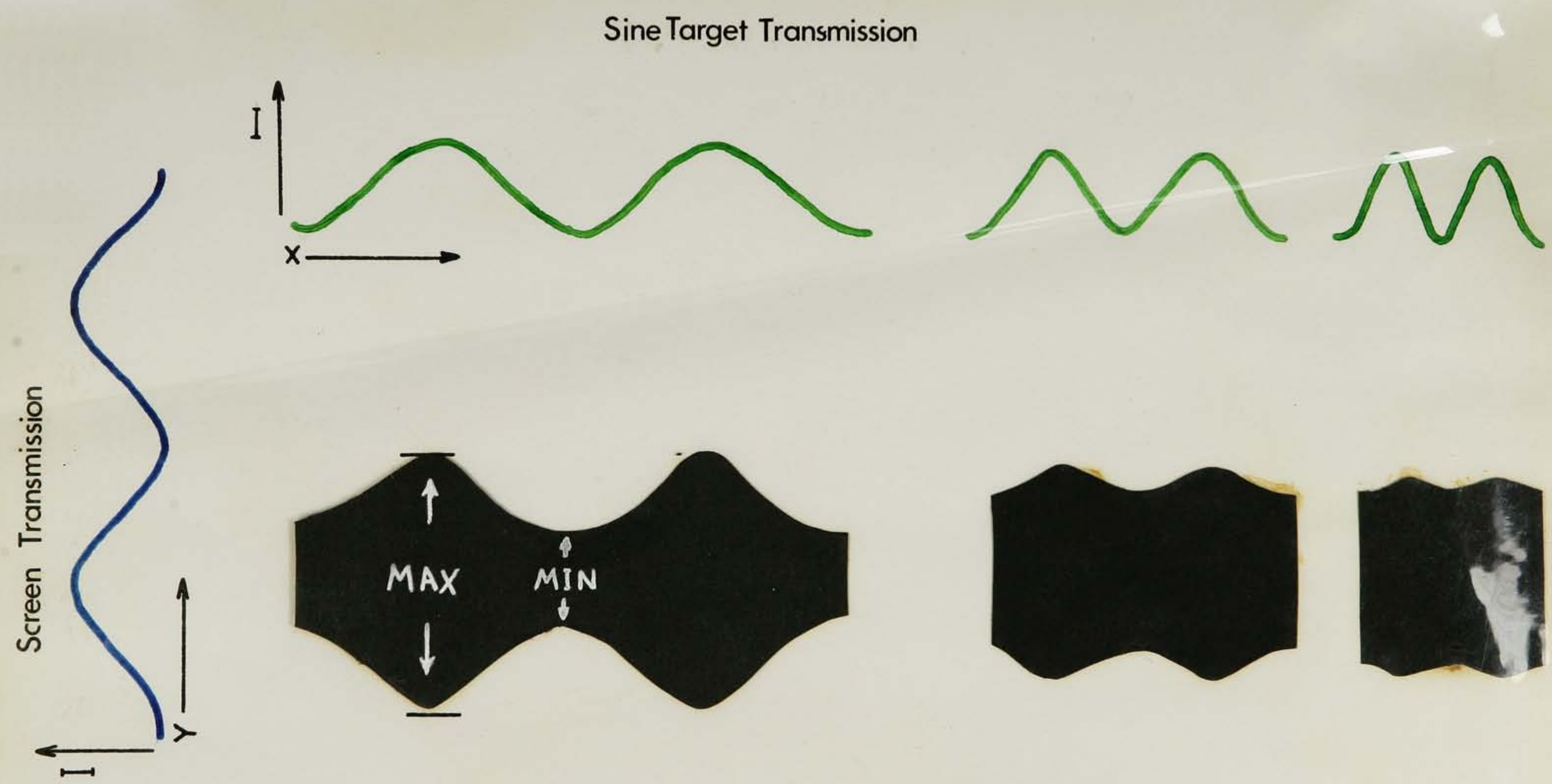


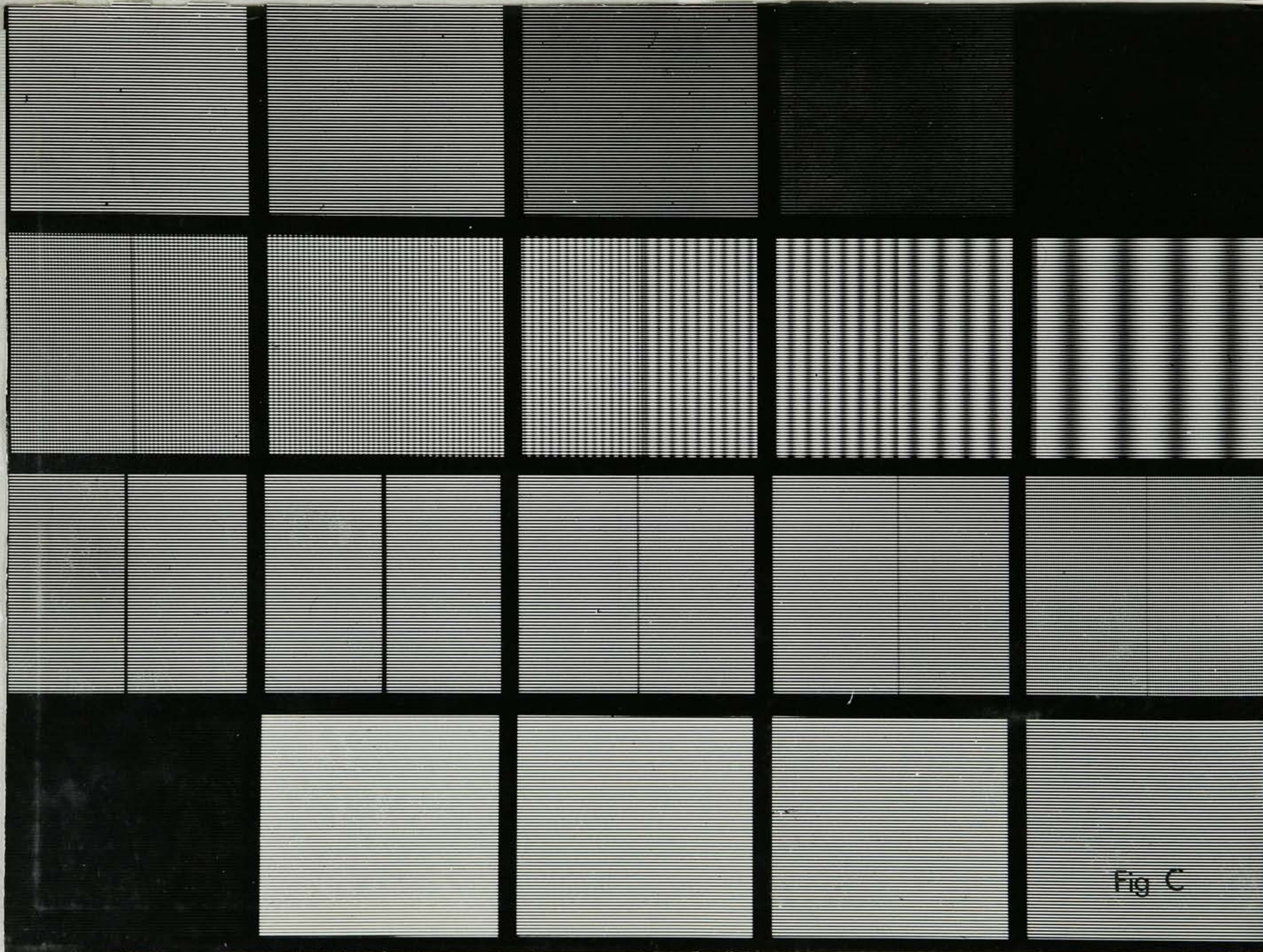
EXPOSURE ARRANGEMENT

fig. A

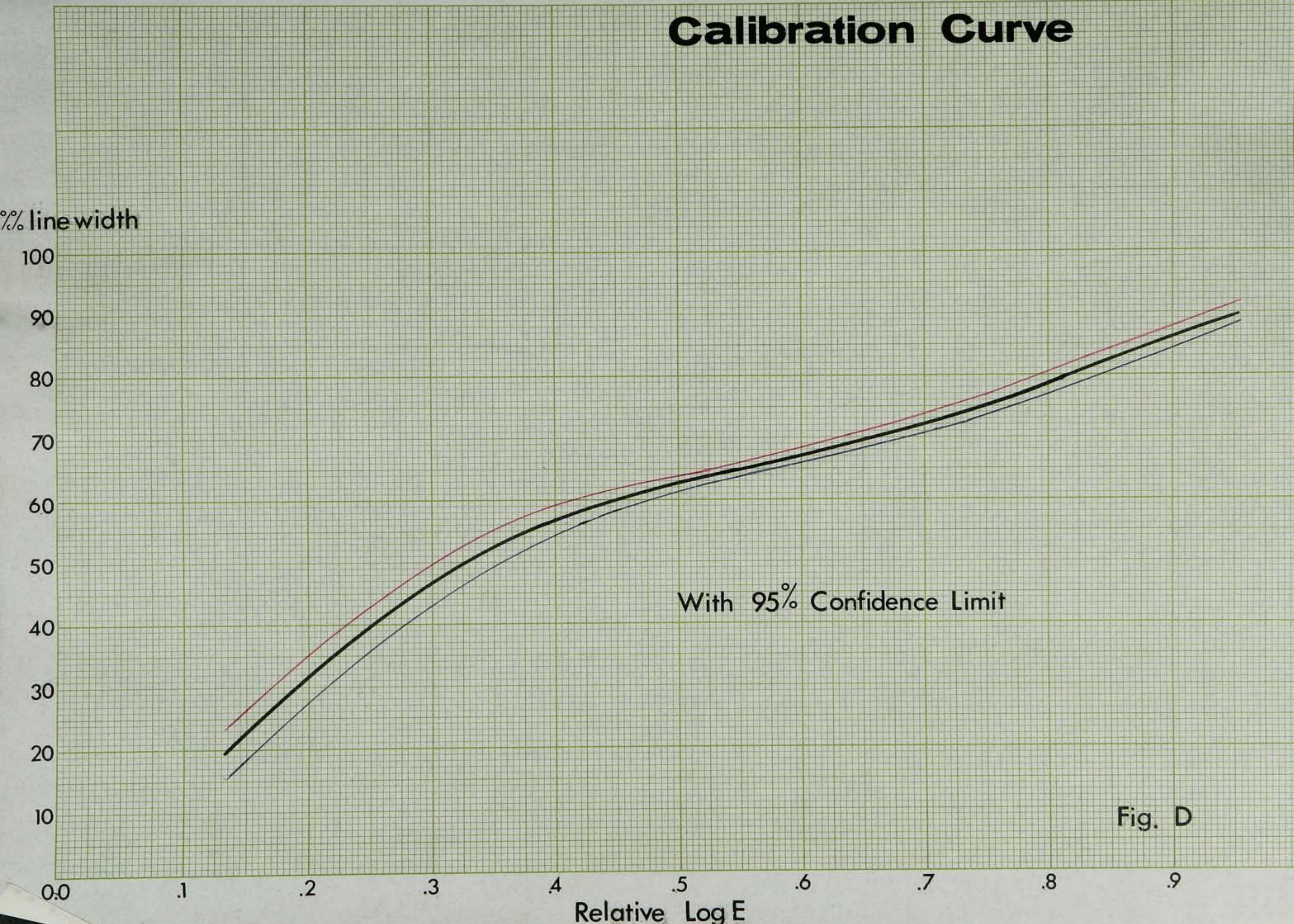


Schemaic of Image

Fig. B



PROJECTION PRINT OF THE SINE TARGET & LINE SCREEN



Calibration Curve
% line width
100
90
80
70
60
50
40
30
20
10
0.0
.1
.2
.3
.4
.5
.6
.7
.8
.9
Relative Log E
With 95% Confidence Limit

Fig. D

Dot Area Meter & Microscope

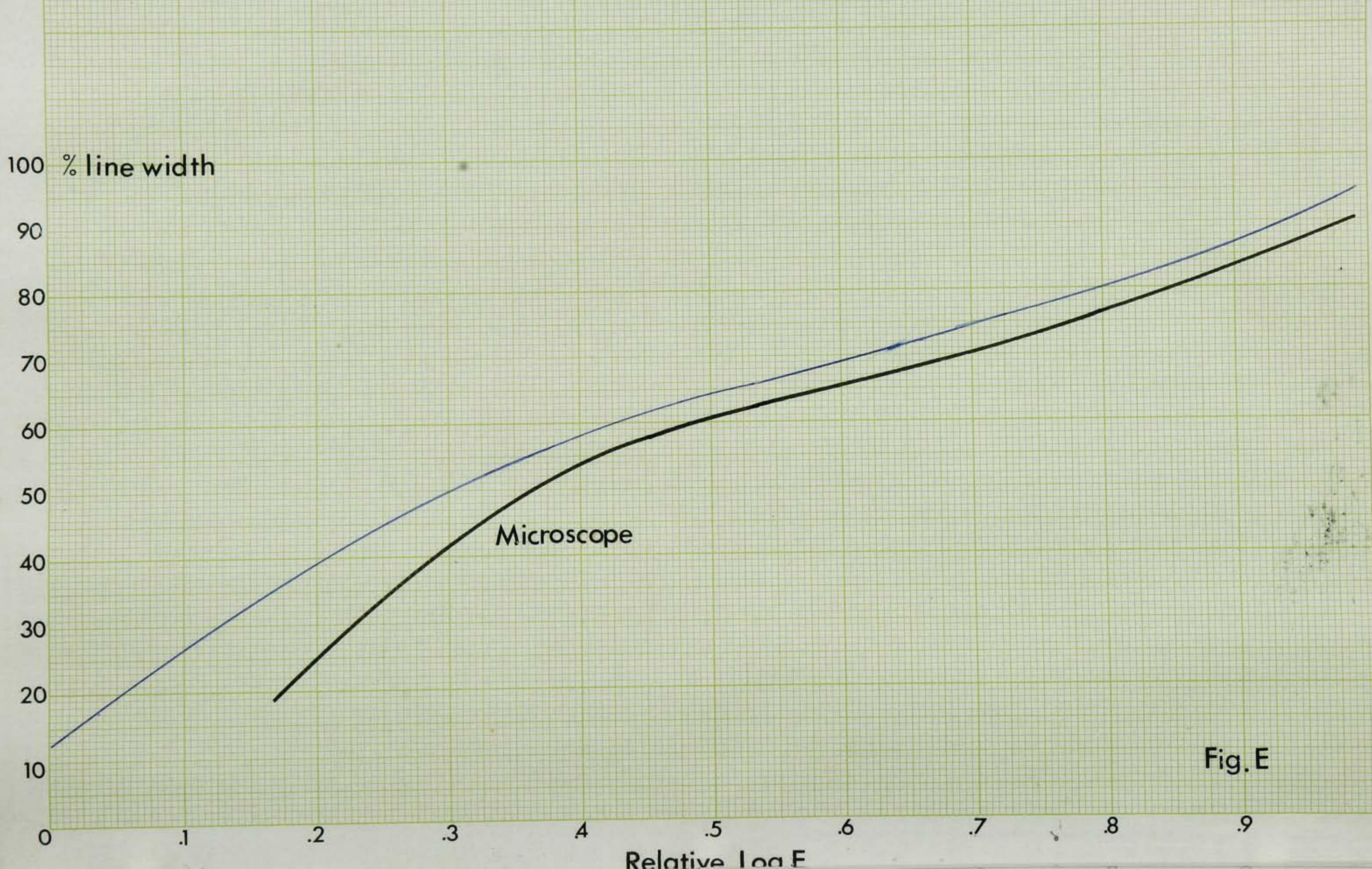
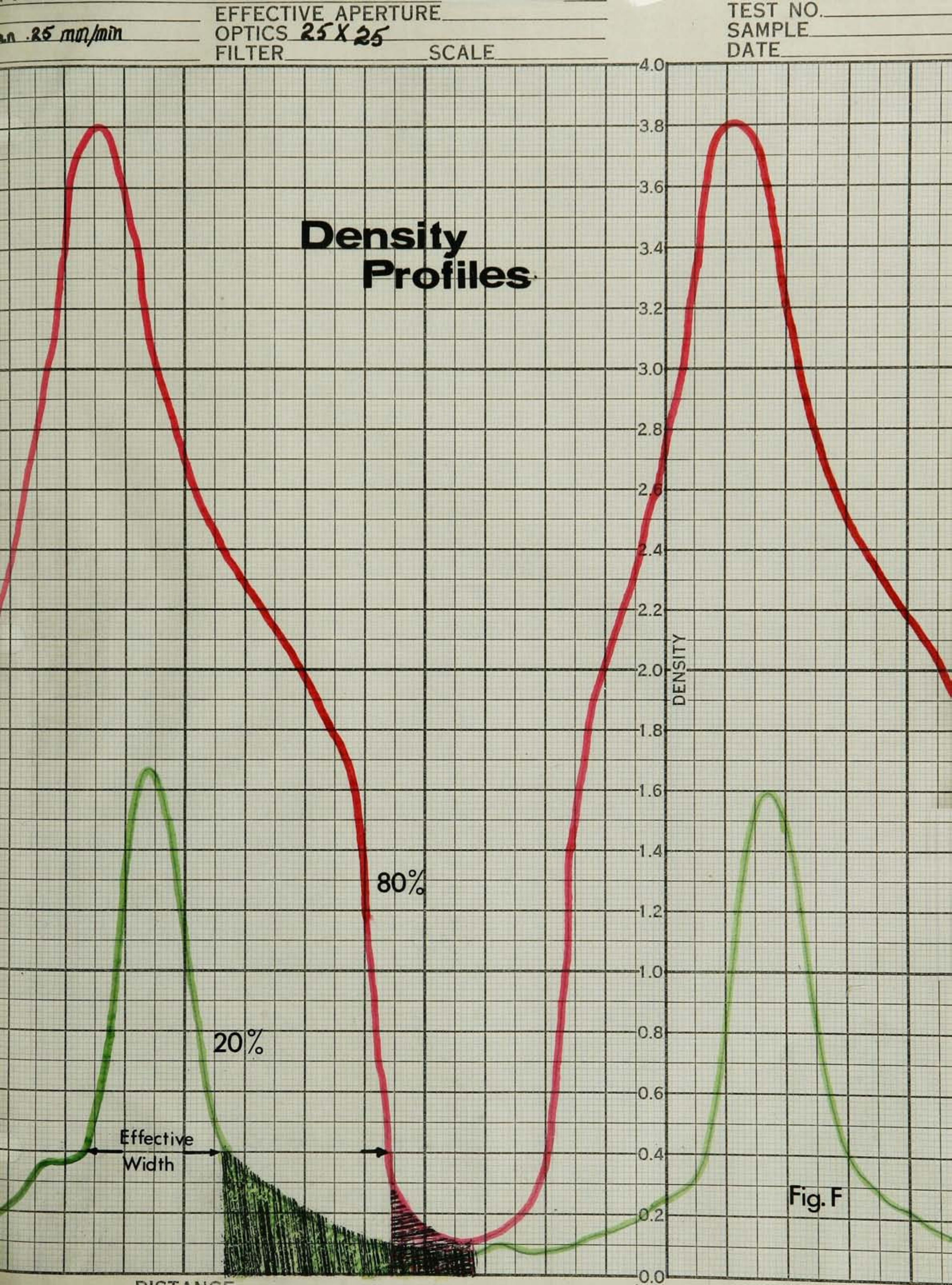


Fig. E


EFFECTIVE APERTURE
.25 mm/min
OPTICS 25 X 25
FILTER
SCALE
TEST NO.
SAMPLE
DATE
Density Profiles
80%
20%
Effective Width
Fig. F
DENSITY
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0

Modulation Transfer Function

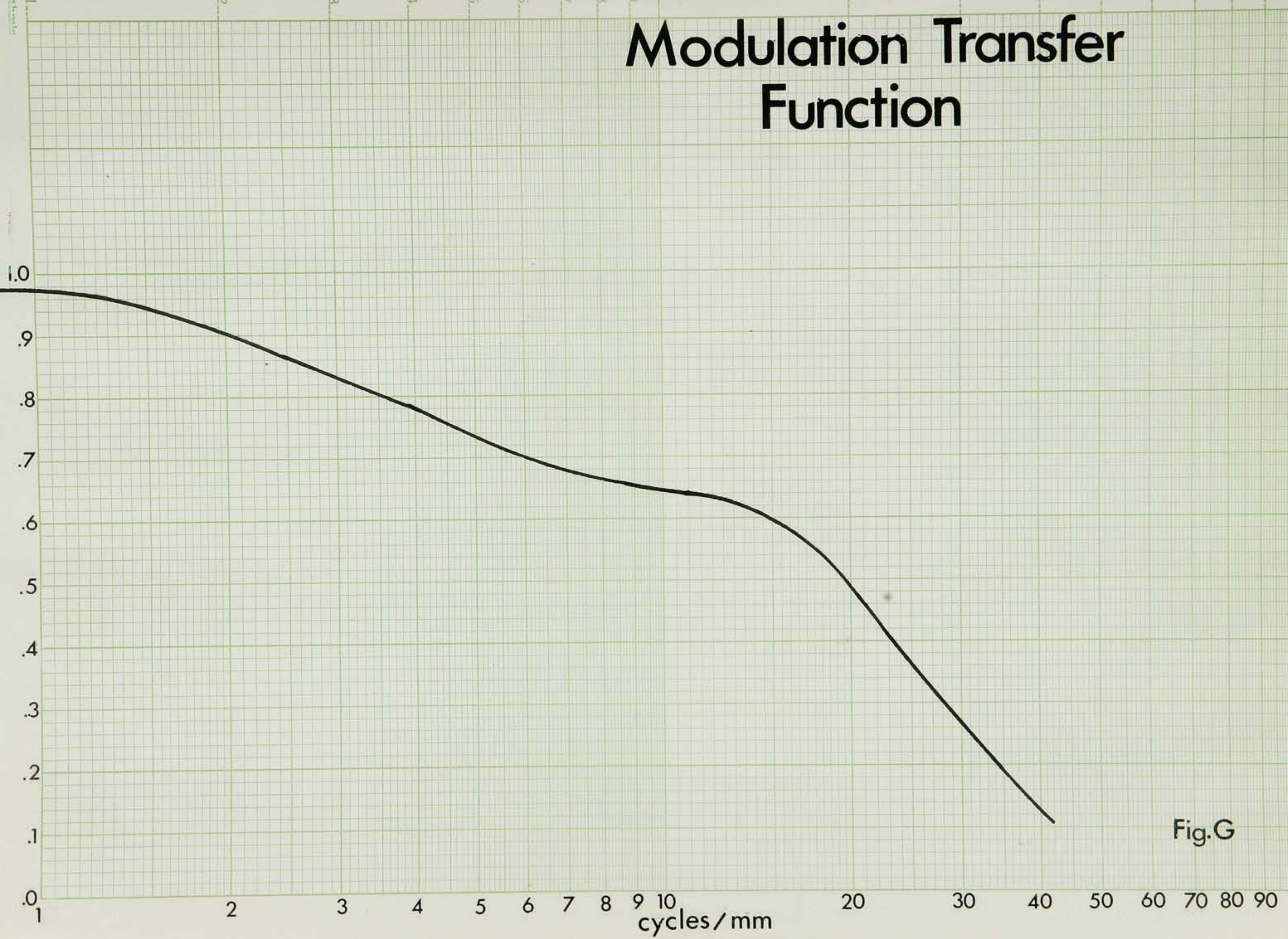


Fig.G

APPENDIX

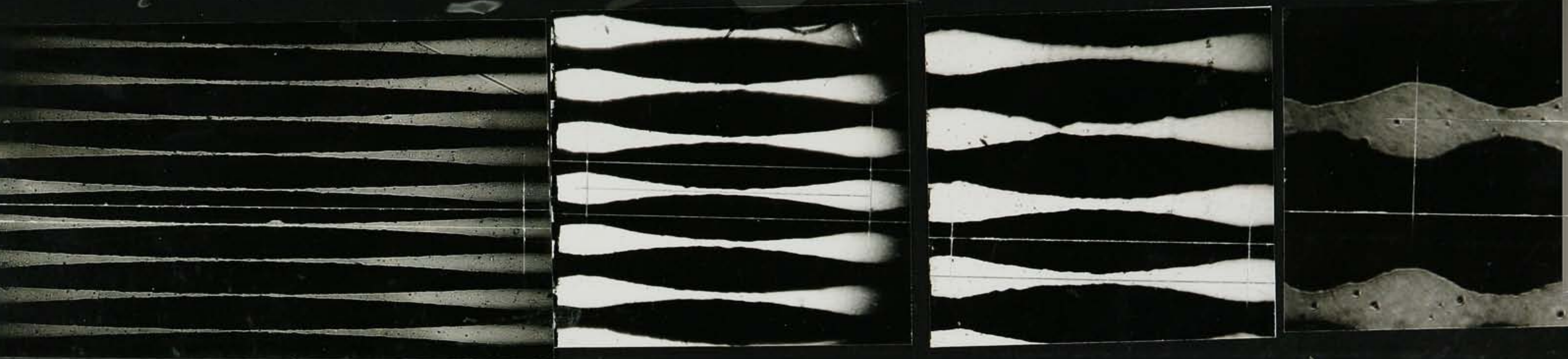
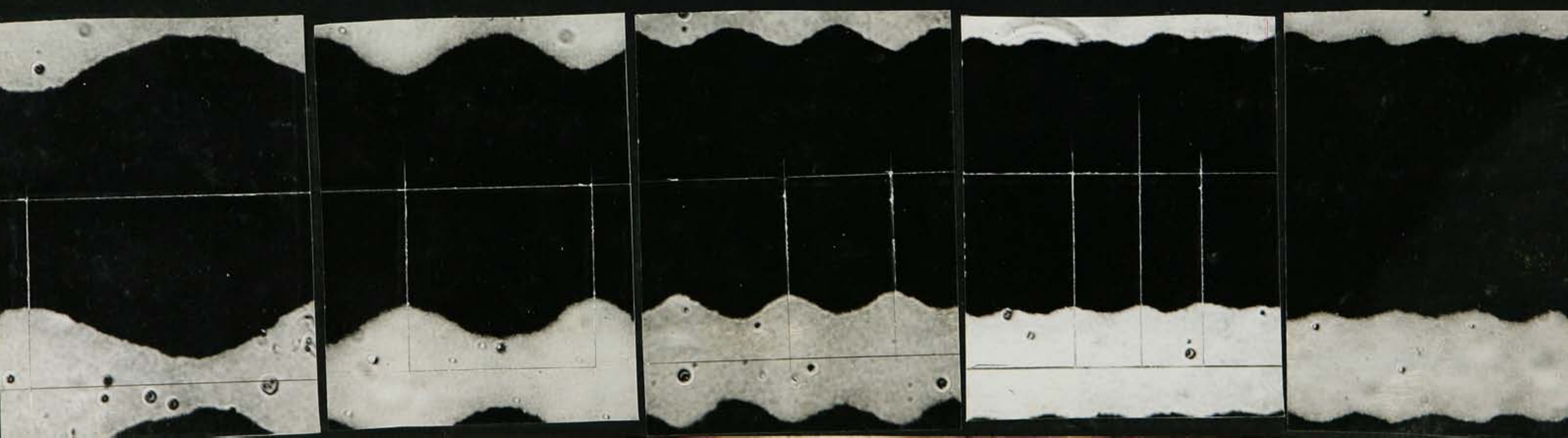


Photo Micrograph of Modulated Image



```
*LIST PRINTER
**      636      KENNEDY-PRICE
       636      KENNEDY-PRICE

C      PRICE - KENNEDY                SENIOR RESEARCH PROJECT
C      CONFIDENCE BAND ON EXPOSURE VS PERCENT AREA CURVE
       DIMENSION A(16,10)
       READ 103,N,M,NSTEP
       XN=N
       PRINT 109
       DO3 J=1,N
       READ 100,(A(I,J),I=1,M)
     3 PRINT100,(A(I,J),I=1,M)
       DO 4 I=1,11
       DO 4 J=1,8
     4 A(I,J)=A(I,J)*24.47
       PRINT 101
       DO 2 I=1,M
       SUMX = 0.0
       SUMX2 = 0.0
       DO 1 J=1,N
       SUMX = SUMX+A(I,J)
     1 SUMX2 = SUMX2+A(I,J)**2
       XBAR = SUMX/XN
       SUMX=(SUMX**2)/XN
       IF((SUMX2-SUMX)/(XN-1.))16,17,17
    16 PAUSE
       SD=1.0
       GO TO 10
    17 SD=SQRT((SUMX2-SUMX)/(XN-1.))
    10 UCL = XBAR+1.96*SD/SQRT(XN)
       LCL = XBAR-1.96*SD/SQRT(XN)
       PRINT 102 ,NSTEP,LCL,XBAR,UCL,SD
     2 NSTEP = NSTEP+2
       CALL EXIT
   100 FORMAT (11F5.2)
   101 FORMAT(///2X,4HSTEP,5X,3HLCL,7X,4HXBAR,6X,3HUCL,8X,2HSD//)
   102 FORMAT (I5,4F10.2)
   103 FORMAT(3I5)
   109 FORMAT(//35X,5H DATA//)
       END
00003 0001
00007 0011
00011 0008
00021 24470000-2
00031 00000000RR
00035 0002
00045 10000000-1
00055 19600000-1
 00065        A 01655  01659       N        01663        M        01667  NSTEP
 01685        I        01695    SUMX        01705    SUMX2        01715   XBAR
 01739      LCL
0103 03658  0109 03696  0003 02000  0100 03416  0004 02188  0101 03456  0002
0016 02926  0017 02970  0010 03066  0102 03610

03774 CORES USED
19999 NEXT COMMON
END OF COMPILATION
```

% Dot Area Meter

COMPUTER STATEMENT OF DATA AND RESULTS FROM DOT AREA METER

Zero On Base

DATA

97.5	89.0	83.0	78.0	73.5	70.0	65.5	63.0	57.0	46.0	39.5	27.5	19.0	13.0	10.0
95.0	87.5	82.0	77.0	72.5	69.0	65.5	59.5	53.0	40.5	34.5	20.5	16.0	10.0	9.0
93.5	86.5	82.0	77.0	73.0	69.0	66.0	61.5	56.0	44.5	37.0	26.0	18.5	12.0	10.0
98.2	89.0	83.5	79.0	74.5	71.0	67.0	63.5	59.0	48.0	42.0	33.0	24.0	15.0	12.0
97.5	89.0	84.0	79.0	75.0	71.0	67.0	64.0	58.5	48.5	42.0	31.0	22.0	11.0	11.0
95.5	87.0	82.0	77.5	73.0	67.5	64.0	59.5	53.0	40.0	32.0	19.5	14.5	11.0	9.0
97.5	88.0	84.0	78.5	74.0	70.0	66.5	63.0	57.5	46.5	40.0	27.5	19.0	13.0	10.0
94.0	86.0	81.5	76.5	72.0	69.0	65.0	58.5	52.0	37.0	30.5	19.0	15.0	10.0	9.0
93.0	85.5	82.0	76.5	72.0	68.0	64.0	58.0	52.0	39.0	31.0	19.0	14.5	10.0	8.0

STEP	LCL	XBAR	UCL	SD
5	94.00	95.7[illegible]	97.04	1.98
7	86.00	87.50	88.37	1.34
9	82.00	82.66	83.29	.96
11	77.00	77.66	78.31	1.00
13	72.00	73.[illegible]	73.97	1.06
15	68.00	69.[illegible]	70.18	1.21
17	64.00	65.[illegible]	66.35	1.13
19	59.00	61.[illegible]	62.[illegible]	2.31
21	53.00	55.3[illegible]	57.16	2.83
23	40.00	43.33	46.11	4.25
25	33.00	36.50	39.5[illegible]	4.64
27	21.00	24.77	28.32	5.42
29	15.00	18.0[illegible]	20.26	3.38
31	10.00	11.66	12.79	1.73
33	8.00	9.77	10.56	1.20

DATA

3.68	3.39	3.18	3.00	2.81	2.66	2.42	2.23	1.81	1.16	.64
3.64	3.40	3.20	2.98	2.85	2.70	2.45	2.21	1.78	1.20	.65
3.67	3.44	3.22	3.00	2.85	2.69	2.48	2.21	1.88	1.18	.59
3.65	3.48	3.13	2.90	2.75	2.67	2.56	2.47	2.26	1.60	1.10
3.62	3.50	3.13	2.94	2.80	2.67	2.57	2.41	2.12	1.53	1.05
3.66	3.48	3.17	2.96	2.85	2.70	2.55	2.39	2.00	1.35	.55
3.78	3.47	3.25	3.01	2.88	2.75	2.61	2.43	2.25	1.61	1.13
3.68	3.40	3.15	2.97	2.78	2.65	2.53	2.35	2.09	1.37	.68

STEP	LCL	XBAR	UCL	SD
5	89.00	89.86	90.68	1.17
7	83.00	84.29	85.03	1.06
9	77.00	77.78	78.51	1.04
11	72.00	72.67	73.29	.89
13	68.00	69.03	69.77	1.06
15	65.00	65.73	66.26	.77
17	60.00	61.69	62.79	1.59
19	55.00	57.19	58.99	2.58
21	46.00	49.52	52.70	4.59
23	30.00	33.64	36.82	4.58
25	15.00	19.54	23.75	6.06

COMPUTER STATEMENT OF DATA(IN RELATIVE UNITS) AND RESULTS OBTAINED FROM THE MICROSCOPE